Air-to-Air Avionics Integration

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What Passenger Demand Will Cause

- More on-time performance (no later than 30 minutes)
- Faster airport throughput on foot
- Reasonable departure times from hubs (the 8 and 5 o'clock hours)
- Greater options to major markets with significant competition
- Service to smaller communities at a cost on the order of the value of time (drive or fly decision)

The consequences:

- **Departure time compression**
- **Greater fleet mix**
- **Greater city-pair demand**
- **Need for greater airport efficiencies and throughput**

NGATS Capabilities

Wants	Needs
• Visual capacities in instrument conditions	• Equivalent visual separation - pilot spacing
• Super density airport operations	• Reduced variability
• Tailored arrivals	• Increased arrivals per hour
• Reduced separation	• Separation assurance
• 4-D trajectory-based separation	• Intent needed for 4-D
• 3X capacity	• 3X capacity

Intelligent Highways

- Following truck uses Doppler radar, GPS, lane sensors and data link to “lock on” to the leader
- Benefit - trucker rests while in trail mode
- Lead is exchanged during travel
- Other vehicles not permitted between lead and following trucks
- An integrated travel management system

Why Not Fly In Formation?

- Military formation flying is a visual flight maneuver
- Formation flying in weather is done by lead with wingmen maintaining visual spacing
- Is commercial civil aviation ready for formation flying?

4X Capacity

The Views From Seat 18A?

- What is needed is something greater than visual contact formation flying as an all-weather capability designed to:
  - Increase situational awareness
  - Reduce workload
  - Provide safety margins greater than that possible with air traffic controllers
  - Deliver significant capacity gains with comfort, convenience, and safety

Paired Flight

What if two aircraft could pair up and fly together with performance matched to all phases of flight?

Why not allow the aircraft to talk to each other using flight command inputs?

- **Outputs of one aircraft become inputs to the other**
- **Changes in heading, speed, power, configuration and touch down are known instantly to correct paired performance**

Electronic Formation

- What if pilots had shared intent information from inputs to the autopilot of another aircraft?
- What if one aircraft could "lock on" to another aircraft and maintain spacing during station keeping - including the approach and landing?

Paired Flight Operations

- **Significant reductions in separation variability and inter-arrival variability**
- **Controlling one aircraft with another in e-formation**

Why e-Formation

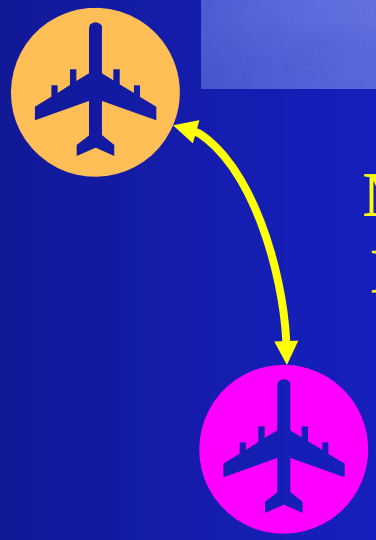
- Increase capacity and reduce separation en route and in oceanic airspace
- Add precision separation with reduced inter-arrival variability on approach
- Enable wake vortex avoidance in instrument weather conditions
- Enable multiple aircraft on the runway
- Provide pilots with automated aids to reduce workload during station keeping
- Provide controllers with separation assurance
- Provide 2X capacity with 1X procedures

Air-to-Air Avionics Exchange

- The sharing of information between aircraft that provides actual commands for the flight controls and configuration of the leading aircraft
- This information set is called “micro-intent” and is well beyond the current scope of ADS-B intent
- “Micro-intent” actually flows from one aircraft (leader) and is processed to control flight of the following aircraft
- Electronic formation flying without visual contact

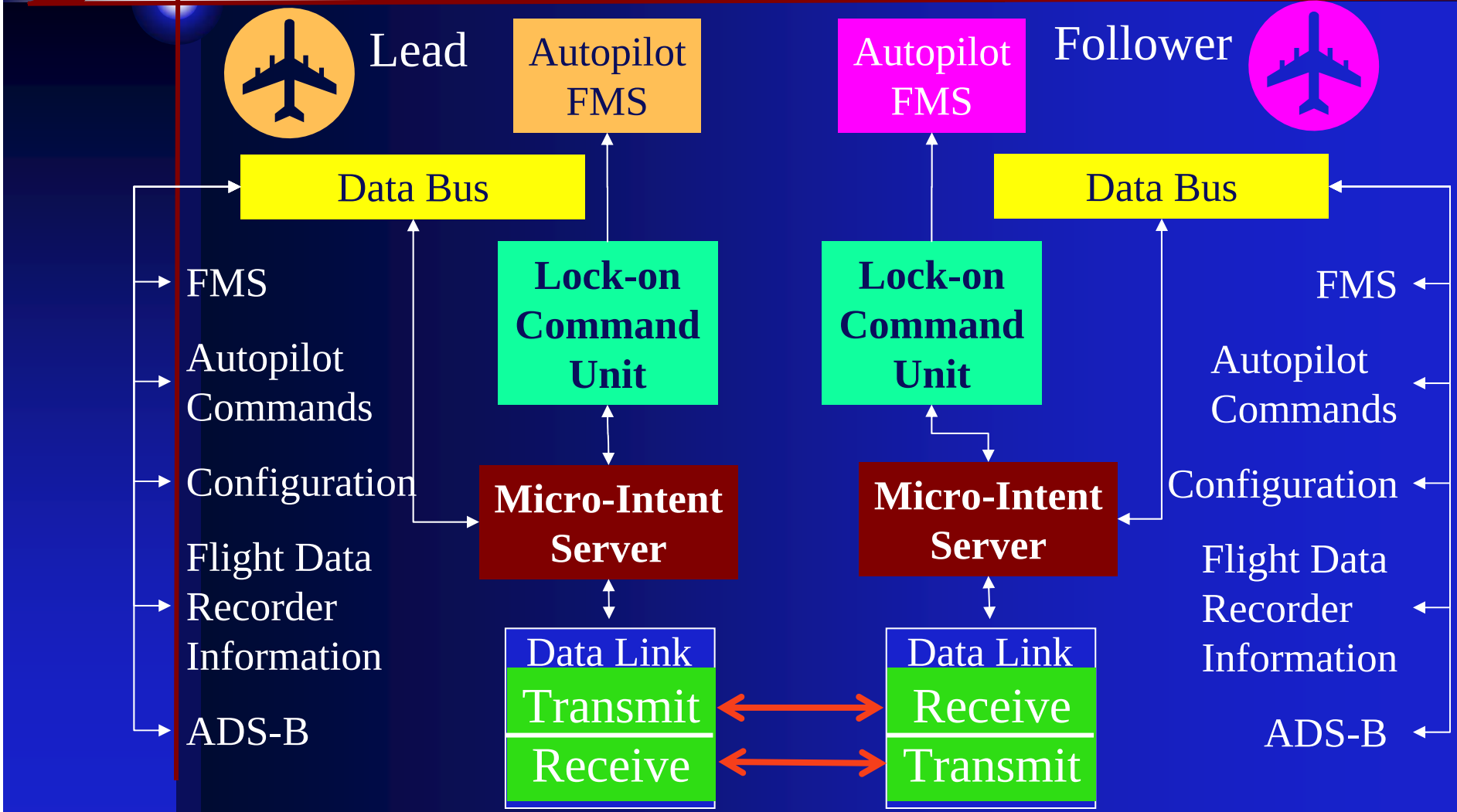
Micro-Intent Data Sources

- Flight Management System
- Flight Data Recorder Bus information
- Flight control input commands
- Weight on gear
- GNSS position information
- Aircraft configuration sensors (spoilers - NOW)



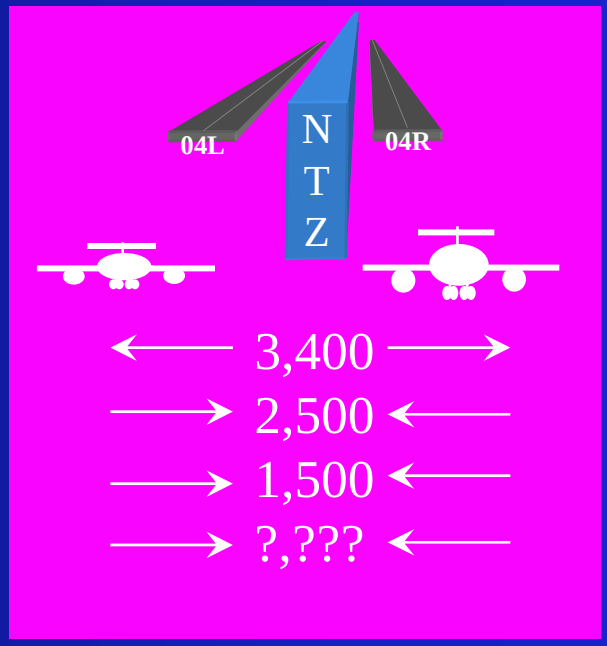
Micro-intent Information Exchange

Notional Architecture



Closely-Spaced Parallels

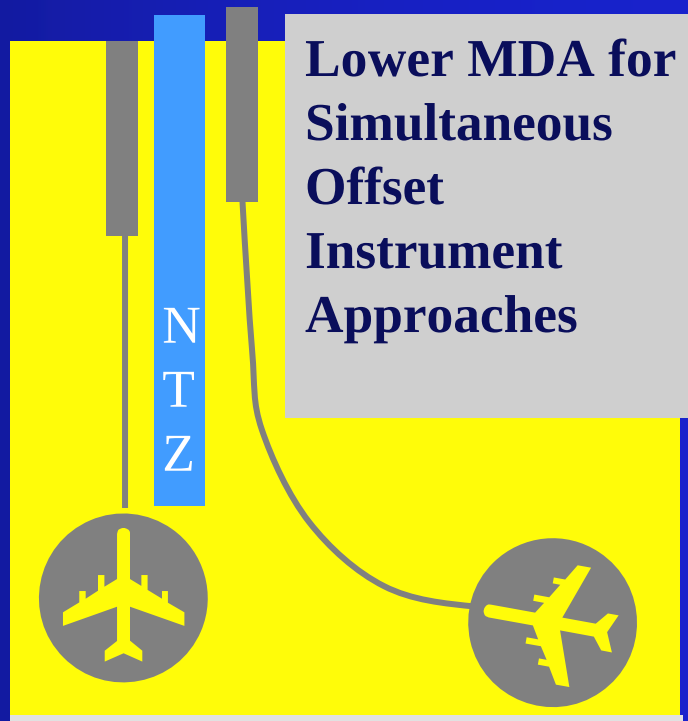
- 3,400 feet with PRM and now multilateration
- 2,500 feet with aircraft-to-aircraft ADS-B
- 1,500 feet with RNP and air-to-air information exchange in a paired approach
- ?,??? feet with micro-intent



Reduced Lateral Separation For Closely Spaced Parallel Approaches

Offset Instrument Approaches

- Lowering minimum descent altitudes where the offset must transition from instrument to visual
- Opening up more runways to the procedures
- Creating increased pilot and controller confidence with “super dense” airport operations

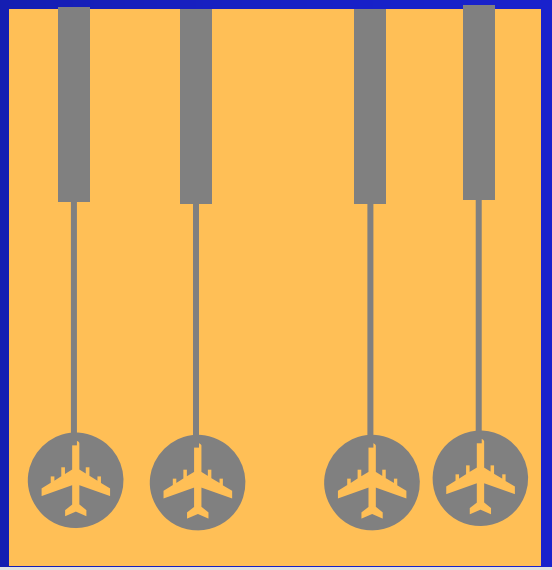


Lower MDA for Simultaneous Offset Instrument Approaches

Introduce Dependent Parallel And Dependent Offsets with Pilot Spacing

Trips and Quads

- How would you fly a four aircraft missed approach?
- Air-to-air avionics integration provides micro-intent with mutual input to aircraft autopilots
- “locked on” for the go



Quadruple **Arrival and Departure Streams with Common Situational Awareness and Ability to Manage Multiple Missed Approaches Through E-Visual Operations**

Paired Oceanic Crossings

Separation established by ATC
Maintained by station keeping

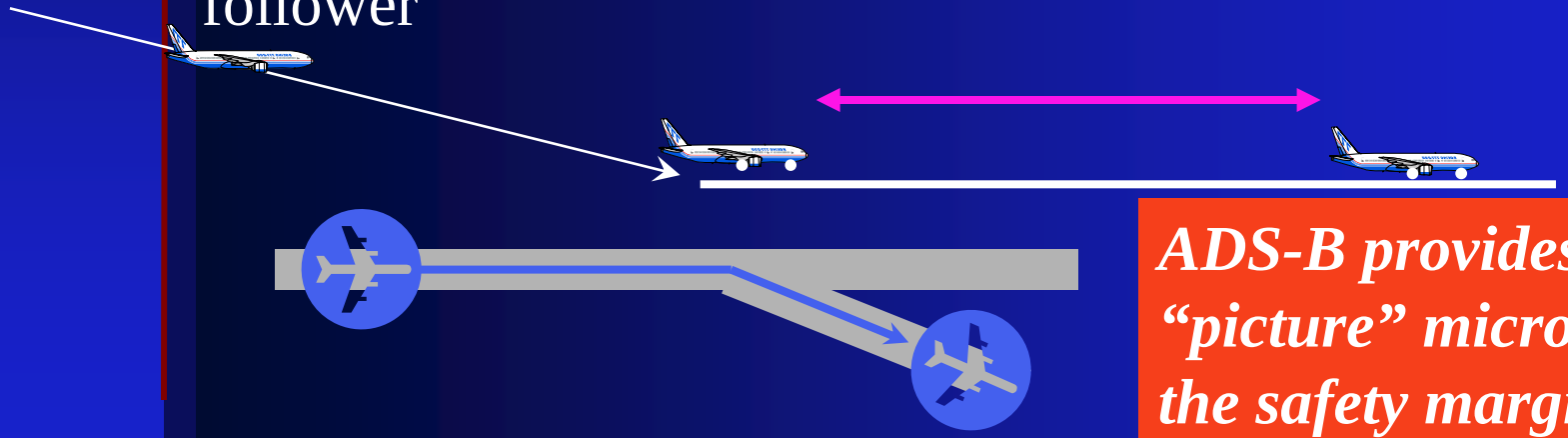
IMC Wake Avoidance

Lock-on for offset vertical glide slope and verified touchdown point of lead aircraft (weight on the wheels position report)

Smaller Aircraft touch down longer than larger aircraft

Two on the Runway

- Knowing current rolling position and deceleration of lead aircraft and nose-wheel steering input for confirmation
- Distance between follower and leader at touchdown of follower



ADS-B provides the "picture" micro-intent the safety margin

Paired Departures

- Single runway departure spacing control of variability
- Single runway pairing for en route city pairs
- Multiple runway aircraft join-ups for paired en route
- Paired passing on climb out

e-Formation Separations

- 3-5 miles en route
- 5 miles paired in oceanic airspace
- Parallel approaches to 750 feet extended runway centerline
- Vertical stacking for wake avoidance
- Two or more aircraft on the runway
- Passing maneuvers for mixed Mach operations
- Separation assurance through station-keeping
- Visual capacities through reductions in inter-arrival variability
- Lower cockpit workload

Far Fetched?

Consider DARPA flocking research for UAV missions

Consider intelligent highways

Consider the possibilities of air-to-air avionics integration